PRECAST ANDPRESTRESSED HOLLOW-CORE CONCRETE SLABS

A Multi-Purpose Cost-Effective Construction Alternative

<u>The Precast and Pre-stressed Hollow-Core Concrete Slab</u>

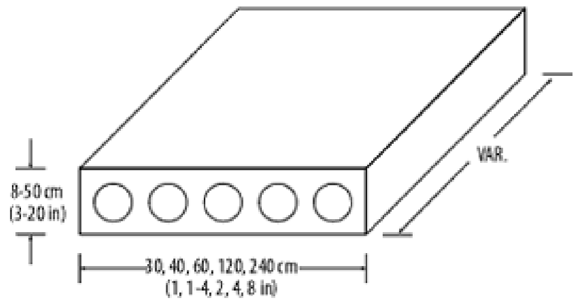
To build a security wall which will withstand the impact of a truck, or a retaining wall which can hold back up to fivetons/m²? Alternatively, is your requirement a fast-track warehouse which is economical to erect and provide a level of strength and durability that far exceeds conventional in-situ walling? Then the best solution is the all-purpose, pre-stressed hollow-core concrete slab.

It was originally conceived and developed as South Africa’s alternative to in-situ cast concrete floor panels for multistory buildings some ٢٥ years ago. In today’s world of innovation and fast-tracking, the pre-stressed hollow-core floor slab is a viable, and in many instances, preferable alternative to more conventional building materials.

There are obvious advantages of simpler, faster construction, not to mention a more durable end product, the secret of applying the material successfully is in the pre-planning.

There are several examples demonstrating theversatility and multiple-purpose functionality of the pre-stressed hollow-core slab. Applications covered include security walls, reservoir roofing, retaining walls, and warehouse walling. Also discussed are two important sub-contracting aspects, down-lighting and tiling, which Apply when slabs are deployed in their more traditional guise as flooring.

But the installation should be done by highly-trained teams, eachof which can after good training lay slabs at a rate of up to ٦٠٠m² a day. A further advantage is that at no stage during the installationprocess is propping a requirement, and brickwork can commence ٤٨ hours after grouting.



Hollow core floor slabs
with depths between ٨ to ٥٠ cm
and widths of ٣٠, ٤٠, ٦٠, ١٢٠, ١٥٠ and ٢٤٠ cm

WAREHOUSES

The use of pre-stressed slabs as retaining walls wassuccessfully applied to a fast-tracking exercise. Adapted from a system originally used in Holland. ١١٠٠m² of wall slabs were erected in a record time of only ١١ working days; the wall contractors being on site for a total of two weeks. Using pre-stressed concrete floors as walls is unusual. Its method more commonly found in the US and Europe.

When the buildings are steel-framed and supported on piled foundations. Precast, pre-stressed panel were slotted into the webs of steel columns. As the things were to be stored to the full height of the walls, very high horizontal forces had to be allowed for in the design stage.

The Warehouse building can Consist storage sheds with built-in galleries for ventilation and temperature control and the structures can be insulated for example with polyurethane foam.

There is an alternative with cast concrete on site and that would take may be longer time. Standard panelprofiles would be used, allowing for normal delivery, minimal adaptation of existing lifting gear, and very shot lead-in times.

FLOORING

Pre-stressed, hollow-core concrete slabs offer several advantages over in-situ floor casting, including speed of erection, lower building costs and consistent quality levels – attributes not often found in one convenient package.

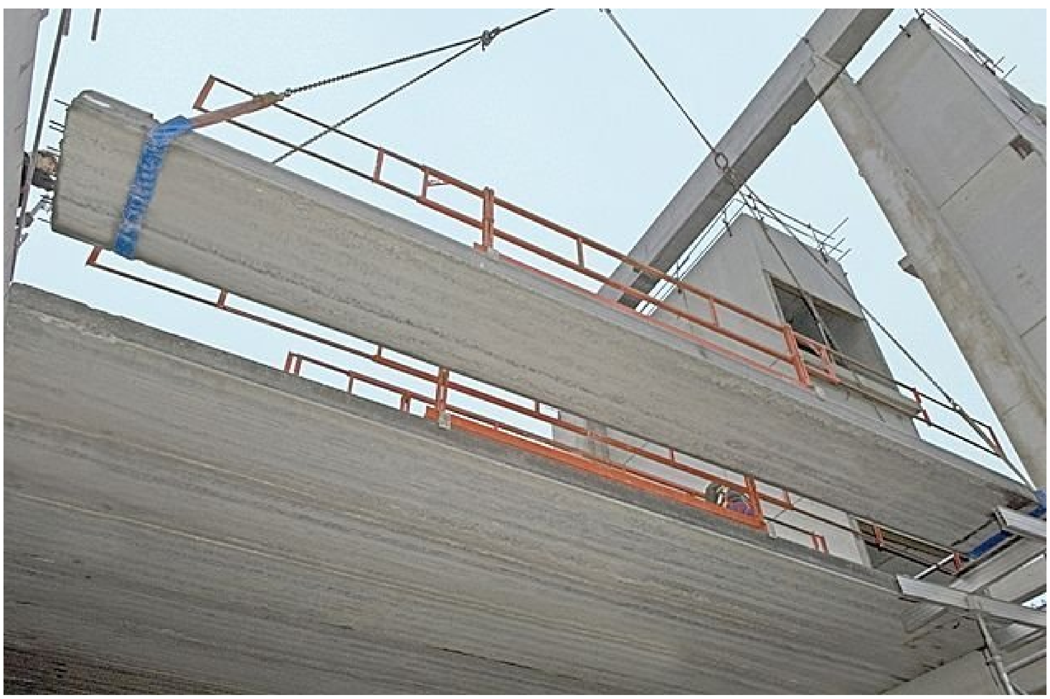
Slabs are most in standard widths of ١٢٠٠mm, in thicknesses of ١٢٠mm, ٥٠mm, ٢٠٠mm and ٢٥٠mm, and in spans of up to ١١m. Non-standard widths are also available and lengths are manufactured to suit individual requirements.

Due to the weight saving – up to a third or more – the use of high-strength concrete, coupled with pre-stressing means that hollow-core slabs can achieve considerably larger spans than in-situ reinforced concrete slabs of similar depths.

The slabs can be used in the construction of virtually any type of building in which suspended floors or roofs are required. These include flats, hospitals, office blocks, hostels, factories, hotels, townhouses, schools, shopping malls, multi-stores car parks and culverts.

But the installation should be done by highly-trained teams, eachof which can after good training lay slabs at a rate of up to ٦٠٠m² a day. A further advantage is that at no stage during the installationprocess is propping a requirement, and brickwork can commence ٤٨ hours after grouting.

The slab soffits are so smooth there is noneed for plastering prior to painting, which is executed using dense-textured paint.Provision is also made for down-lighting; service holes of up to ٧٥mm in diameter can be cut on site through the hollow sections and, when required, larger holes can be factory formed, subject to a maximum of ٥٦٠mm". Larger holes can be accommodated but require alternative designs and strengthening. Hollow-core slabs are also well suited to ground floors inareas prone to clay heave and shrinkage.



Pre-stressed hollow-core slabs are cast according to Customer dimensions

SECURITY WALLS

There are many examples for this application;some of them are outstanding examples,which serve to illustrate this application. Walls were constructed to safeguard military equipment another built for the Post Office.

When the areas are between ٢٥٠٠m^2 and ١٠ ٠٠٠m^2, the walls can be constructed with slabs measuring ٤m x ١.٢m. Each wall topped ٣m, with the additional one meter section sunk into a foundation of soil Crete, a mixture of compacted gravel and cement.

There are several advantages to this typeof walling, speed of erection being one of the majorconsiderations.

The current cost of building a precast security wall ٣m high, is approximately half the cost of a wall offering the same properties if cast on-site. Furthermore, it would take twoto three times as long with no advantage in strength or durability.

Also there is no requirement for shuttering or propping, on-site curing and formwork, and the installation rate is approximately ٥٠ linear meters per eight hour day.

DOWN-LIGHTING

The fitting of down-lights into hollow-core slabs is fastbecoming the preferred lighting solution thanks to theincreasing use of precast hollow-core concrete floor slabs and improved lighting technology, the latter having led to smaller lights and enhanced performance. Other factors influencing the swing to down-lighting include the recent changes to municipal requirementsboth for large concrete light boxes and for single transformer units.

Cairns noted that compared to fitting light boxes and conduits using the more traditional in-situ floor casting method, installing down-lighting in precast hollow-core slabs offer several advantages.

Light points are far simpler and easier to place then in in-situ floor construction. This now requires much larger transformer boxes to be positioned between steel reinforcement, and the boxes are also difficult to position accurately.

Costs are also lower as wiring and single light transformers can be installed the day after installation. The traditional method involves fitting larger light boxes, which are now more expensive than coring costs, and placing conduits before concrete is poured. Furthermore wiring can only begin once shuttering and scaffolding have been removed some two to three weeks later,”observes Cairns. Down-light coring is simple and accurate and far more economical than the installation of light boxes. Larger holes can be factory formed subject to a maximum diameter of ٥٦٠mm and any edge chipping can be easily repaired with rhino lite or a similar material. Modern lighting equipment is a lot more compact, allowing for ancillary equipment to be stored in slab cores.

A ١٢-volt single light transformer requires a minimum core of ٧٠mm. This allows for short cylindrical transformers to be easily removed and replaced during maintenance.

Longer transformers require larger cores. Smaller cores of ٥٠mm or less can be used for ٢٣٠-volt down-lights, which do not need transformers.

A scientifically monitored experiment has proved that drilling core holes through the steel reinforcement of a hollow-core slab does not adversely affect performance. During theexperiment, slabs were loaded and deflections measured. Aprofessional civil engineer assessed the results and found the slabs to be well within allowable tolerances.

Reservoirs

Hollow-core slabs are making a contribution to the storageof clean, potable water, being used as they are for the closure and roofing of water reservoir. They present the consulting engineer and building contractor with several advantages, time saving, with an installation rate of ٣٠٠ - ٤٠٠m² per day, being the most important.

For instance, a closure contract which would normally take٨-١٠ weeks to complete using in-situ casting, takes only ١٠-١٤ days when pre-stressed slabs are deployed. The fact that no on-site curing, nor props, nor shuttering, and only minimal formwork, are required, is another distinct advantage.

As an Example one recent southern African project was a ٣٥٠٠m² (٣٠ ٠٠٠m³) reservoir for the supply of fresh water to industrial and residential areas in. Six meter by ١,٢m precast hollow-core slabs were laid on concrete beams and columns. Service holes were drilled on site as opposed to manholes which were precast.

Waterproof plastic sheeting would be placed on top of the completed roof which in turn covered with a sloped layer of screed to facilitate the drainage of rainwater. In some instances a layer of aggregate is then thrown over the screed for additional weather related protection.

Retaining Walls

All applications are purpose-designed to bear specific loads.Time saving is the major advantage here, with installations running at ٣٠٠-٤٠٠m² a day and contracts generally completed up to four weeks ahead of schedule.

Another major advantage is the fact that building work can continue prior to the erection of a retaining wall which usually takes place during the installation of floor panels. Others include the possibility of window openings and no requirement for formwork or propping.

Two prominent projects which demonstrate the effectiveness of the system include the mixed office/retail/ residential development at Melrose Arch in Johannesburg where a ٣٥ linear meter wall was erected, and a new Johannesburg Hyundai dealership in the suburb of Bryans ton, where the completed wall was ٤٥ linear meters. When used as retaining walls, the panels are generally twostory's high (٦-٧m) and ٢٥٠mm deep. Unlike floor slabs, which are cast with pre-stressed steel cables at the bottom to form a positive camber, wall panels must be as straight as possible, and are therefore cast with cables at both the top and bottom of the slab, and then evenly stressed.

Wall panels are delivered on site with ready-made holes to facilitate lifting into position. They can be simply hoisted off a truck and placed onto a concrete foundation with an insidekicker beam. It is then bolted to an overhead beam.

TILING ON SUSPENDEDFLOOR – AVOIDING THECRACKS

Fixing of ceramic tiles onto precast hollow-core suspendedfloor slab systems, or onto any concrete suspended floor slab, requires special attention if cracking is to be avoided. Flexible adhesive is the answer; nevertheless several basic rules must be followed to ensure success.
These include:

• All new concrete work or screeds must cure fully before any tiling proceeds. Surfaces must be clean and free of all traces of curing agents, laitance, loose particles and sand, or any other surfaces contaminants.

• Power-floated or steel-trowelled surfaces must either be scarified or keyed with slurry consisting of cement and a "Key coat" type product. Specifications are obtainable from various adhesive manufacturers. The adhesive must be applied while the slurry is still "tacky".

• The adhesive itself should always remain flexible to counter the possibility of cracking, whereas rigid adhesives – as most are – will transfer any minor racking through to the tile. To obtain this type of Flexible adhesive, manufacturers have developed liquid bonding additives which replace water when mixed with the cement-based power adhesive. Alternatively, high polymer cement-based adhesives are suitable for use where extra flexibility, high strength or water resistance is required. These adhesives require no additives; they are simply mixed with water and will maintain the necessary flexibility to avoid cracks.

Prestressed HOLLOWCORE PROVIDES THESE ADDITIONAL ADVANTAGES

- ALL WEATHER CONSTRUCTION

Pre-stressed hollow-core slabs can be placed the job under inclement weather conditions. They are precast, cured and cut to required lengths at the manufacturing plant where Quality Control can be most effectively exercised. With due precaution, groutingcan be carried out even in low temperature.

- WORK DECKS

Immediately after erection, a working surface is provided for other trades. Under good conditions and proper scheduling, over ١٠,٠٠٠ square feet of hollowcore have on been placed in one day by a crew and a crane.

- ATTRACTIVE INTERIORS

The underside of a Pre-stressed hollow- core slab has a smooth finish, resulting from the steel pallets uniform casting surface and close Quality Control during the manufacturing process. In buildings such as warehouses and garages, Pre-stressed hollow-core ceilings present an attractive appearance just as they are. For dwellings, painting is the only finish required.

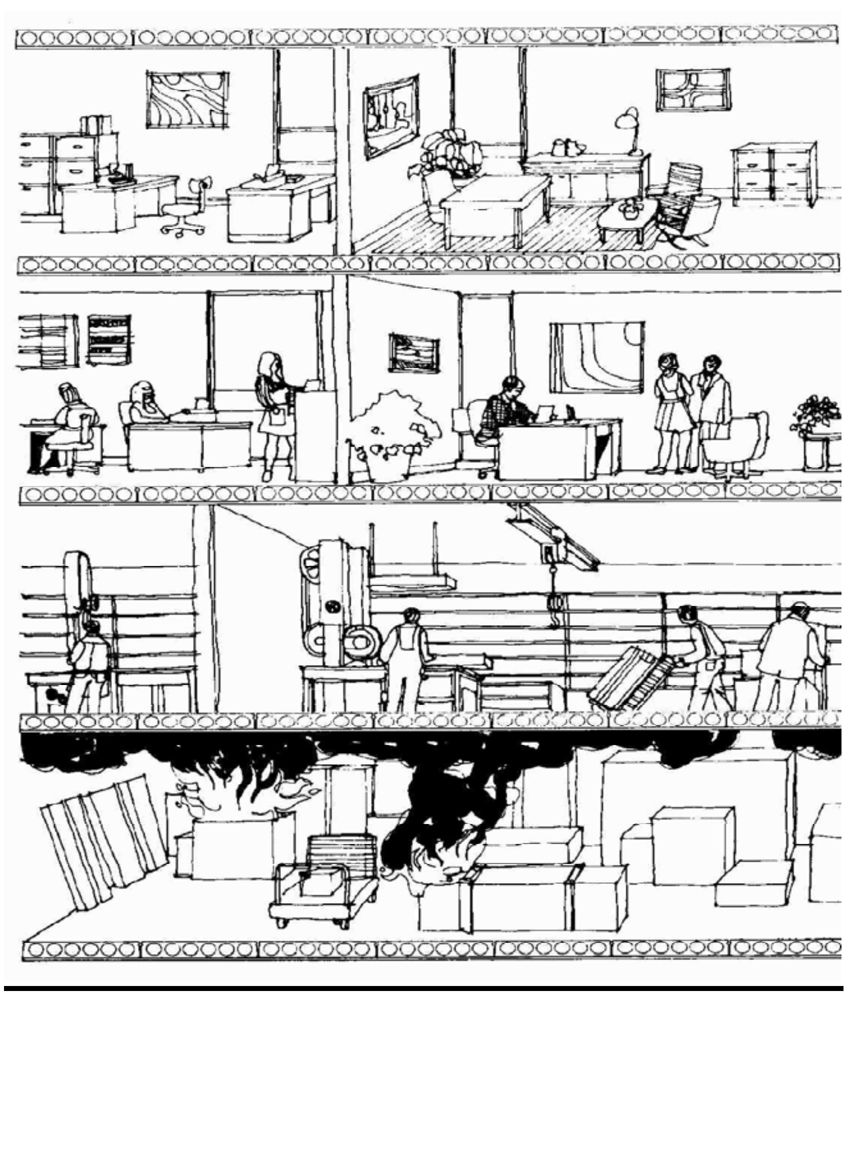
Pre-stressed HOLLOWCORE MEANS QUIETER BUILDINGS PLUS TOP FIRE RATING

- FIRE RESISTANCE

Fire tests and studies carried out by leading authorities have demonstrated the high performancecharacteristics of Pre-stressed Hollow-core slabs. Two hour fire ratings are achieved without additional topping. The addition of topping will produce ratings up to four hours, which will satisfy even the most stringent code requirements.

- THERMAL RESISTANCE PROPERTIES

Precast and pre-stress concrete construction with their thermalinertia and thermal storage properties has an advantage over lightweight materials.



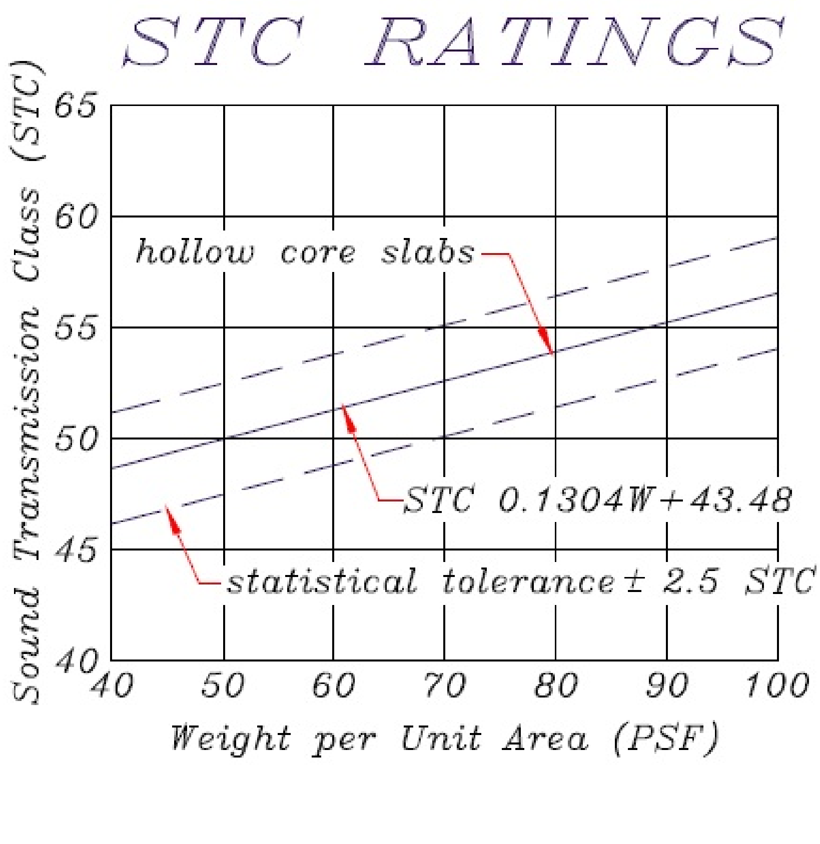
- LOW SOUND TRANSMISSION

Sound control is essential in building construction to ensure quiet buildings for pleasant living and working conditions. Sound transmission can be divided into two categories:

١. Impact Sound (footsteps)

٢. Airborne Sound (voices or radio)

The density and the configuration of pre-stressed hollow-core combine to lend themselves extremely well to control of both impact and airborne sound transmission. Control of airborne sound in a room is readily accomplished by proper finishes. For effective control of impact sound transmission, installation of carpet finishes over hollow-core floor is desirable.



Classification of Damage and its causes as applied to precastConcrete buildings

The mass construction of buildings and the drive to find anadequate method for fast and rational construction haveresulted in the development of a set of precast systems.

The application of precast residential buildings and hallsis particularly widespread. In the prefabrication ofmembers, steam-curing is applied for the faster hardeningof concrete. This influences the specificity of damage toprecast concrete structures. In order to provide therequired quality it is necessary to respect certain criteriafor the assessment of members and their connections intothe structure. For this assessment considerable help isgiven by developed classifications of damage and itscauses. These classifications are also a basis for decisionmakingin the process of repair and/or strengthening ofstructures.

A great number of papers deal with the classificationof damage to masonry buildings monolithic or reinforcedconcrete structures. Considerably smaller space isdedicated to the classification of damage to precastconcrete buildings. This paper deals with the mostfrequent kinds of damage and their classificationaccording to the appearance and possible causes ofoccurrence. Emphasis is given to structural members andjoints and connections, due to their important influenceon the stability of buildings. Comments are also given onthe mechanisms of deformation and failure, particularlyunder seismic forces.

CLASSIFICATION PRINCIPLES

The form and severity of damage in the first place dependon the type of member, the method of connectingmembers, the structural systems and the environmentalconditions. Precast members have to meet specifieddemands from stripping to erecting, as well as in service.

According to the shape of vertical bearing members,precast concrete buildings are mainly divided into framedand panel buildings. The kinds of damage in both types ofbuildings are specific and have different influences on theirstability. Members behave differently in handling, evenwhen their role is identical but the dimensions aredifferent. Their behavior under loading and in servicedepends on their position in structures.

The specificity of a precast concrete structure results inthe first place from the method of production of members.Due to their mass production, series members are madewith reduced dimensions relative to similar members inmonolithic structures. This is the reason why damage inprecast members is more frequent. The classificationaccording to the severity of damage is very important.Damage can influence the stability, durability andserviceability. In classification an important aspect is thedetermination of a dominant influence on damage and itsduration. A specific aspect is the influence of environmentaland local conditions on damage through changesof material properties, and bond and anchorage deteriorationin the supporting zones and reinforcement splices.In a structural sense, damage reduces the stiffness andinfluences the redistribution of forces.

According to the seriousness, damage to buildings canbe full or local failure. Damage can also be divided intodamage caused directly and indirectly.

DAMAGE TO MEMBERS

Damage to precast structures very often differs fromdamage to monolithic structures. Some kinds of damageare characteristic only for members prefabricated in largeseries, such as

(i) A short regime of thermal concrete treatment,

(ii) Use of fine-grained aggregate with higher water/cement ratio and moving mass,

(iii) Thin walls with little concrete protective cover anduncompact cross-sections,

(iv) Inadequate formwork removal,

(v) Transportation of precast members and storage,

(vi) Loading which occurs during assembling.

Damage and its causes are described,as well as damage mechanisms in specific characteristicexamples. The aim is, on the basis of these descriptions, toestimate the influence of these kinds of damage upon theservice characteristics of members and structuresthemselves.

Cracks

Due to the given specificities, cracks in precast (Pre-stressed Hollow-Core) concretestructures can be found more often than in monolithicones. The main causes of cracks are as follows:

(i) Concrete shrinkage,

(ii) Temperature influence,

(iii) Settlement,

(iv) Structure deformation,

(v) Insufficient and inadequate reinforcing.

The cracks in precast (Pre-stressed Hollow-Core) concrete structures can be classified in various ways. According to the intensity they can bedivided into:

(i) Insignificant cracks with openings up to ٠.١ mm,

(ii) Small, up to ٠.٣ mm,

(iii) Developed, ٠.٣-٠.٥ mm, and

(iv)Large

The cracks appear under normal service conditions andtheir widths are limited depending on the type ofenvironment. In the majority of countries these limitationsin designing are: ٠.٣ mm in mild environments,٠.٢ mm in moderate environments and ٠.١ mm in severeenvironments.

The ACI [٧] gives a somewhat different division ofCracks according to their width: fine (generally < ١ mm),Medium (١-٢mm), and Wide (>٢mm).

According to the depth of propagation the cracks canbe:

(i) Surface, and

(ii) Deep.

According to the direction of cracks the division is asfollows:

(i) Vertical and horizontal,

(ii) Longitudinal and transversal, and

(iii) Diagonal.

According to the character of formation (development)they are divided into:

(i) Isolated,

(ii) Parallel,

(iii) Crossed,

(iv) Miscellaneous.

These cracks occur in slabs, beams, columns and othermembers. The occurrence of cracks can be caused by thefollowing:

(i)Non-uniform pre-stressing of reinforcement,

(ii) Insufficient protective concrete cover,

(iii) Holes for anchorage bolts,

(iv) Irregularities in concreting formworks,

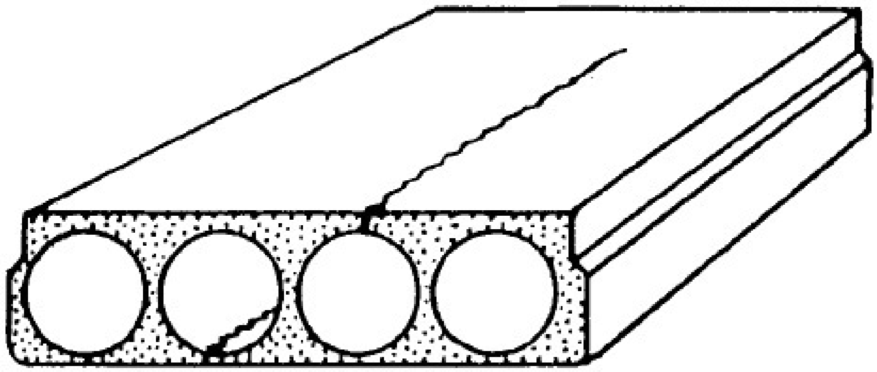
(v) Pre-casting procedure,

(vi) High temperatures during welding of memberConnections.

During the assessment of cracks it is necessary todetermine their position in relation to the reinforcement,opening, quantity, length and time of occurrence. It is veryimportant to separate old cracks from new ones whichdiffer in the degree of filling with dust and other materials,the colour and the manner of branching.

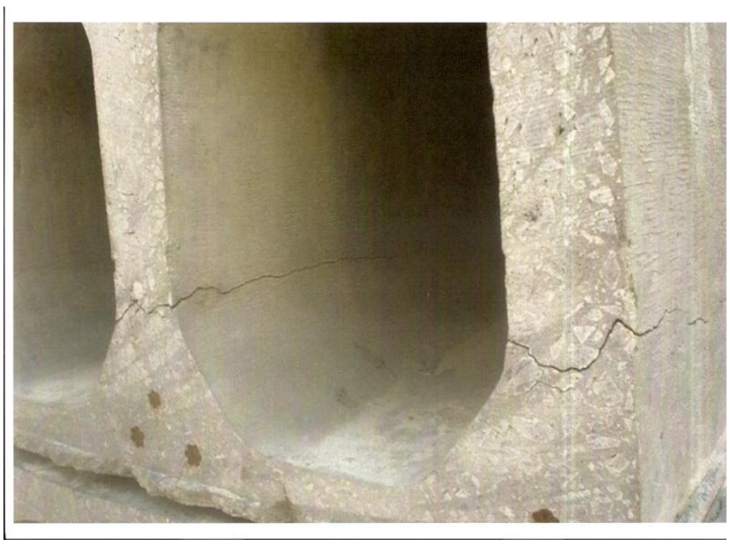
Two papers by a PCI Committee [٨,٩] give cataloguesof cracks which occur in members during production,storage and handling until their complete assembly. Thefirst paper [٨] presents possible kinds of damage tohollow-core slabs and TT beams, occurring in the form ofcracks. These papers include the causes of occurrence ofcracks, manner of prevention and their influence onstability, as well as recommendations for repair. Thepresent paper considers only the cracks occurring duringprefabrication and handling. This is intended as a controlfor acceptance of these members before their assembly inorder to assess the causes of crack occurrence, as well astheir influence on the quality of works that should becarried out with these members. Depending on the cause,the cracks have different locations and forms.

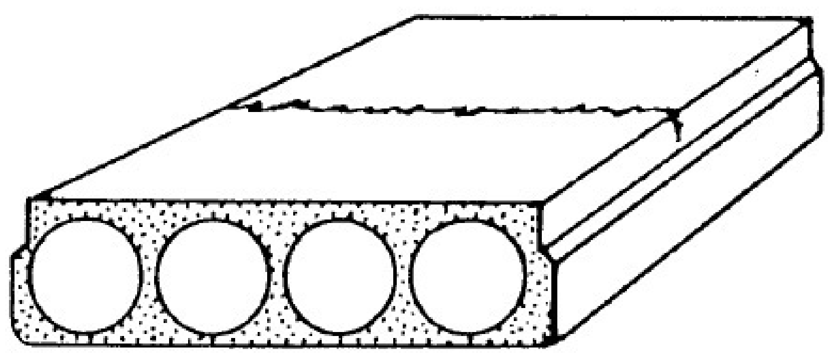
(Fig. ١)illustrates the damage which occurs in the form ofa longitudinal crack. Transverse cracks across themember are presented in(Fig. ٢).



Longitudinal cracking of hollow-core slabs.

Fig.۱





Cracks across hollow-core slabs.

Fig.٢

The causes of longitudinal cracking are:

(i) Transverse shrinkage,

(ii) Improper handling,

(iii) Differential compaction,

(iv) Placement and eccentricity of pre-stressing steel,

(v) A thin flange because void forms are moved.

Transverse cracking is caused by:

(i) Longitudinal shrinkage,

(ii) Contraction due to heat-curing,

(iii) Excessive top-fiber tension,

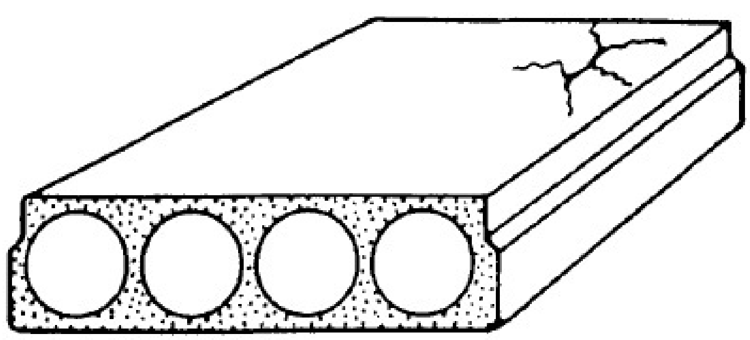
(iv) Insufficient cover on transverse reinforcing bar.

The miscellaneous cracks in (Fig. ٣) appear due to:

(i) surface shrinkage,

(ii) Improper trowelling,

(iii) Improper mixes.



Miscellaneous cracks in slabs.

Fig. ٣

The TT – beams showed in (Fig. ٤) show horizontal cracks in the ribs. The causes of horizontal end-cracks in ribs are:

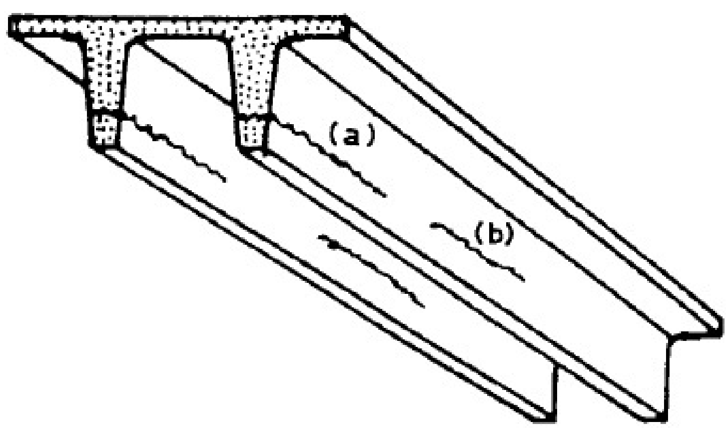
(i) Improper design (inadequate confining of reinforcement,Excessive pre-stress force),

(ii) Improper release,

(iii) Improper stripping and handling,

(iv) Improper production.

Fig. ٤

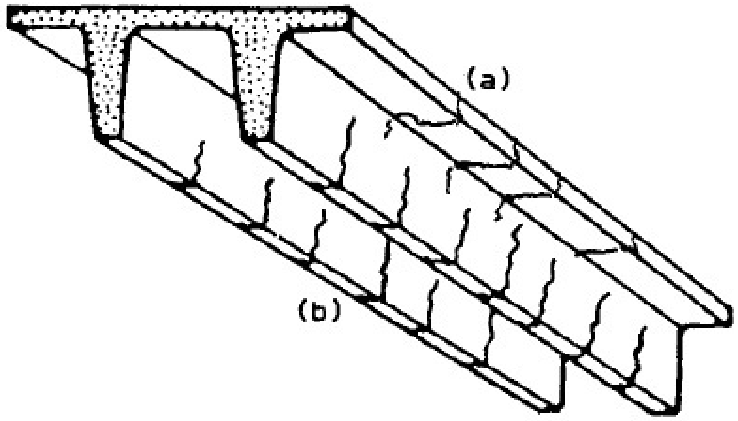


Horizontal cracks in ribs: (a) end cracks, (b) cracks in mid-parts of ribs.

Horizontal cracks in mid-parts of ribs, besides thosementioned, are also caused by improper positioning ofreinforcement.

Vertical cracks at the top of a member and verticalcracks at the bottom of ribs are presented in (Fig. ٥).Vertical cracks at the top of a member occur due toexcessive cantilevers, excessive eccentricity leading toexcessive top-fiber tension, and vibration caused byshipment. Vertical cracks at the bottom of the ribs occurdue to improper production, storage or handling,improper pre-stressing, bond failure at the end of amember, and errors in design values of erection stresses.

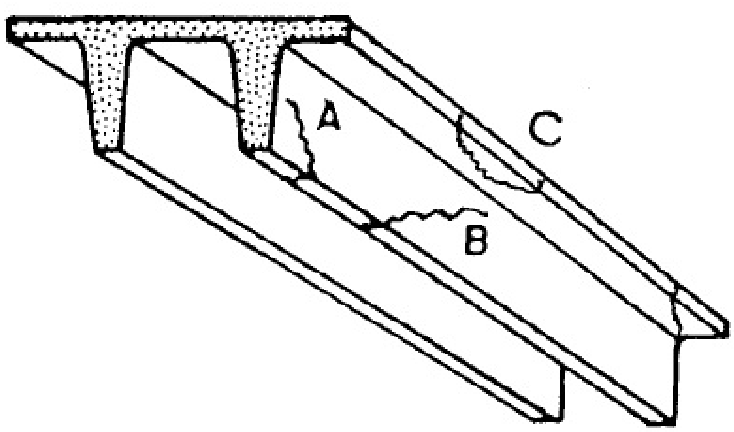
Fig. ٥



Vertical cracks of TT-beam: (a) cracks at top of member, (b) cracks at bottom of ribs.

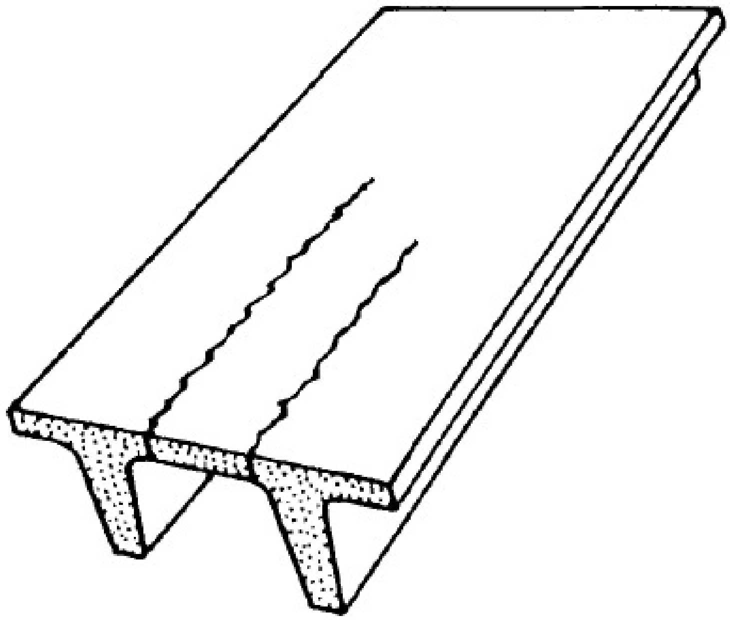
Diagonal cracks in ribs (Fig. ٦) occur due to diagonaltension caused by the sliding of the member as pre-stressis released, excessive bearing stress, sudden expansion ofthe form due to rapid heating, transverse movement ofmembers, and improper production. Flange cracks oncantilevers are caused by insufficient flange reinforcement,binding at the edge of the form, bumping of edgesduring handling, and load transmitted to an unsupportedflange. Parallel flange cracks between ribs (Fig. ٧) arecaused by improper and incomplete consolidation,improper stripping, and volumetric change.

Fig. ٦



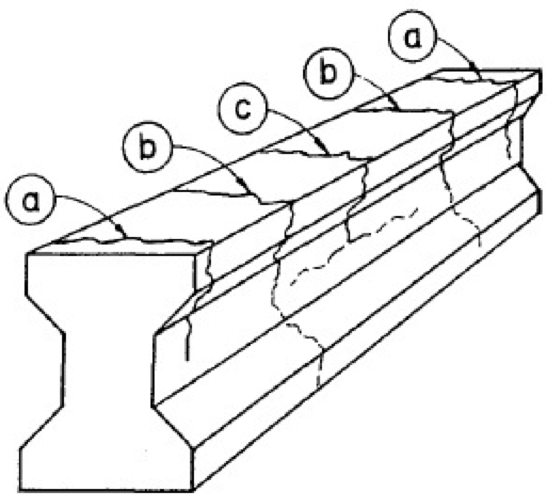
(A, B) Diagonal cracks in ribs and (C) end-flange cracks on cantilever.

Fig. ٧



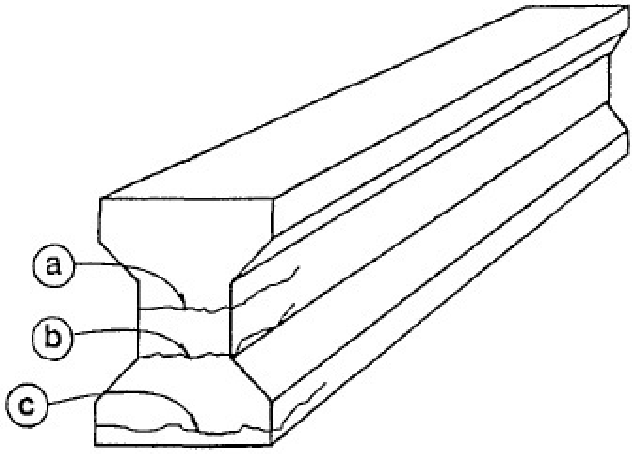
Longitudinal cracks between ribs and flange.

Transverse cracks at the top of beams are presented in(Fig. ٨). Cracks of type (a) occur due to inadequatetemperature treatment, and those of type (b) due to excessive fiber tension. Horizontal end-cracks in web orflange are shown in (Fig. ٩). They occur due to differentialstress between web and flange.Ledge corner cracks are presented in (Fig. ١٠). These arediagonal cracks occurring at the edge of a flange.



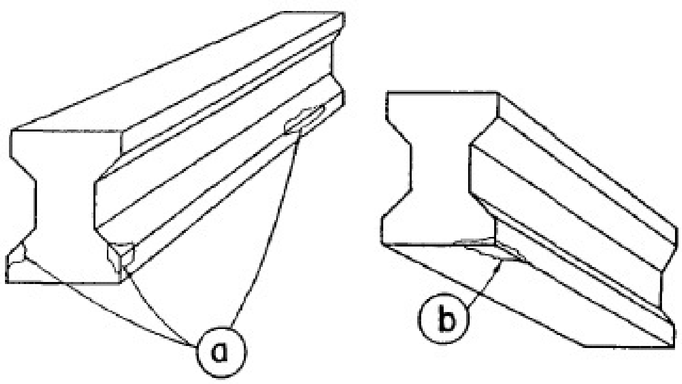
Transverse crack at top of beam, located (a) near end of beam, (b) between end and centre of beam, (c) near centre of beam.

Fig. ٩



Horizontal end crack, located (a) in the web, (b) at the junction of web and flange, (c) in the bottom flange.

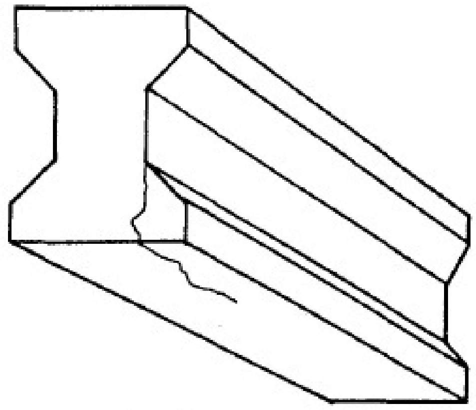
Fig. ١٠



Diagonal cracks at the edge of the flange, located (a) at top of ledge, (b) at bottom of ledge.

Ledge corner cracks as given in (Fig. ١١) are caused byimproper production and insufficient reinforcement.Miscellaneous cracks also occur in beams. These are fine,shallow cracks occurring at the top surface of the beam.

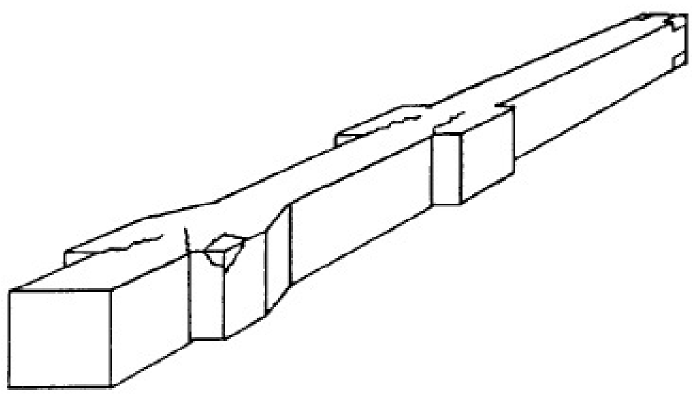
Fig.١١



Ledge crack in a beam.

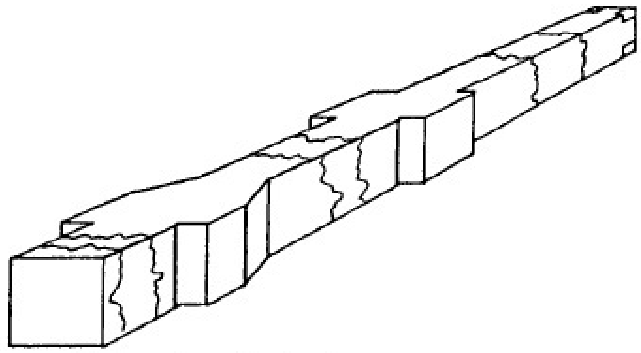
Crakes in columns occur most frequently in corbels.Interior corner cracks in a corbel (Fig. ١٢) occur due toimproper production, handling and storage. Horizontalcracks as shown in (Fig. ١٣) occur due to improperhandling, production and shrinkage. They are often linedup with stirrups and extend completely around themember.

Fig. ١٢



Interior and exterior cracks in corbel of columns.

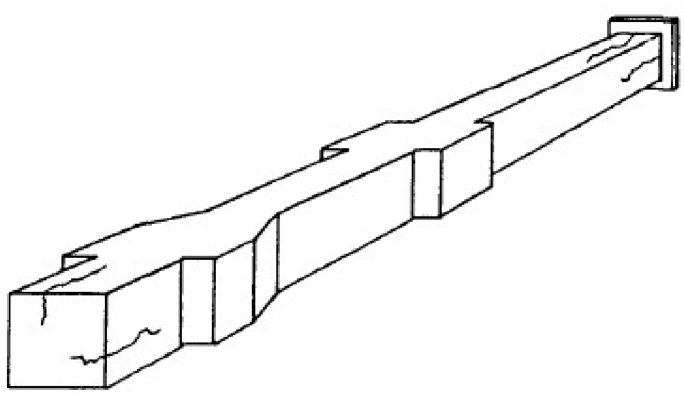
Fig. ١٣



Horizontal cracks in column.

Vertical cracks at ends (Fig. ١٤) occur due to improperproduction, handling, storage and stripping. These cracksbegin at the end of the column and extend longitudinally.Usually, they are located in the plane of a strand.

Fig. ١٤



Vertical cracks at the end of a column.

From this review of the possible kinds of damage it isevident that they appear in the first place as surface damage and in the form of cracks. Spalling appears in thecase of insufficient concrete cover, and later in the storagecorrosion of reinforcement occurs. Damage rarelyappears due to improper concrete strength, incorrectreinforcement position or incorrect dimensions. Dependingon the extent of damage spread over the member andthe depth of cracking, damage can be classified as follows:

(i) Damage affecting the aesthetic appearance of themember,

(ii) Surface damage,

(iii) Structural surface damage.

The first group includes smaller changes in membercolour, dirt, and non-uniform aggregates on the surface.All this has little influence on functional effects. Surfacedamage, besides minor cracks, includes spalling of cover,corrosion of metal parts and concrete, as well as the localweakening of bonds.

The third category includes those kinds of damagewhich do not meet the structural demands, wider cracksand damage to cross-sections, greater local deformations,concrete quality failure, partial anchorage disturbance,and greater corrosion and stiffness reduction of amember. Before application, the members from thiscategory should be tested or rejected.

The structural behavior of wall panels is influenced bythe following:

(i) Type, geometry and tolerances,

(ii) Openings and slenderness,

(iii) Edge

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